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ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

PROJECT NO. 2 - HIGH TEMPERATURES IN TANKS

Final Report On

Sub-Project No. 2-6, Determination of Water and Salt Requirements
for Desert Operations

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ARMORED FORCE MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

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Project No. 2-6
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1. PROJECT: No. 2 - High Temperatures In Tanks. Final Report on Sub-Project 2-6, Determination of Water and Salt Requirements for Desert Operations.

a. Authority - Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNOHD, dated September 24, 1942.

b. Purpose - To extend the information obtained in the desert field study, previously reported. Project 2-6, November 12, 1942.

2. DISCUSSION:

a. Methods - Four studies were carried out on a total of fifty-six enlisted men living in the hot room of the Laboratory. The periods of study ranged from one week to two months for the various groups. The results of other investigations carried out simultaneously are included in Report on Project No. 2 (2-11, 2-12, 2-13, 2-17) File No. 727.2, April 3, 1943.

b. Environmental conditions - Dry bulb temperature was maintained at 120°F from 0800 to 1700 hours and at 90°F during the remainder of each 24 hours. Details of the procedures and results are given in the appendix.

3. CONCLUSIONS:

a. Water Requirements.

(1) Daily water requirements are contingent upon the environmental temperature and the severity of physical work. Water requirements therefore vary with the duties of troops, and the locale and season.

(2) In a hot climate man dissipates the greater portion of his heat by the evaporation of sweat. Failure to supply sufficient water to make up for that lost in sweating results in the depletion of body water. If continued, this results in progressive loss in weight, physical deterioration, reduced efficiency and capacity for work, and greatly impairs morale and motivation. Reduction of water consumption to levels below that required to maintain water balance will be followed by in-

capacitation, whether the reduction is gradual or abrupt.

(3) A schedule which requires that a man disregard thirst and drink only at meal-time results in no saving of water and may cause discomfort and reduced physical performance.

(4) Thirst is an inadequate indicator of rapid tissue dehydration. At the high rates of sweating which accompany even moderate work in the heat, men will consistently drink less water than they are losing as sweat. Augmenting the water intake so as to balance the fluid lost in the sweat will increase the amount of work which can be done on first exposure to heat and reduce injurious effects.

(5) The daily water requirement is not significantly changed as men become acclimatized to heat.

b. Salt Requirements.

(1) The requirement of salt is in direct proportion to the amount of water taken.

(2) With exposure to heat, the need for extra salt is greater during the early days than after acclimatization is established.

4. RECOMMENDATIONS:

a. Water Requirements.

(1) That the following daily requirements for drinking water be used as a guide in determining supply of water to troops in desert areas.

<u>Activity</u>	<u>Illustrative duties</u>	24-Hour Fluid Requirements (quarts Per Man) When Maximum Daily Temperature is:		
		95°F	105°F	115°F
Light to moderate work	(Desk work, (Tank operation over smooth terrain	4	6	10
Moderate work	(Tank operation over rough terrain, (Marching at normal rate	5	7	11
Strenuous work	(Engineers' operations, (Forced marches, (Entrenching operations	7	9	13

(2) That the above allotments be increased by one (1) quart per day when the K-ration is used.

(3) That additional water be issued for vehicles, for cooking, and for toilet purposes so that the above water ration may be reserved for drinking.

b. Salt Requirements.

(1) That one (1) gram of extra salt be taken for each quart of water consumed. The following methods of administration may be used:

(a) Adding extra salt in the preparation of food.
(b) Using extra salt at mess.
(c) Addition of salt to drinking water in the following proportions: 1/4 teaspoonful per quart, two 10-grain tablets per quart, or 0.3 pounds in 36 gallons (Lister bag). This is the method of choice when above methods of salt administration are not practical.

(d) Direct ingestion of salt tablets is not recommended. They should be dissolved in the drinking water as directed in (c) above.

(2) When no food is taken, it is imperative that salt be taken with water.

(3) When no water is available, or where the supply is reduced, extra salt should not be taken.

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Appendix with Table 1,
and Figures 1 thru 7

APPENDIX

A. EXPERIMENTAL CONDITIONS AND PROCEDURES

The following experimental conditions were employed in the "Hot Room" studies:

1. The environment - Air temperature during the day (0800 hours to 1700 hours) was maintained at 120°F; during the night, at 90°F. One hour was required to change from one temperature to the other. The relative humidity ranged between 15% and 22% during the day. Wall and floor temperatures were in equilibrium with air temperature. Additional radiant energy was not supplied. Air movement of moderate degree was obtained from two 26-inch fans or from four 10-inch fans.

2. Experimental subjects - 56 enlisted men; 48 lived continuously in the room, 8 lived in their barracks, reporting to the Laboratory for exposure periods.

3. Preliminary training - Before entering the hot environment, all men worked for one week at cool temperatures (70°F to 76°F). This accustomed the men to the work which they were to do later and produced a comparable state of physical fitness in all subjects.

4. Clothing - Men wore what they chose; during the hot periods, only cotton shorts, shoes and socks; during the preliminary cool period, regulation fatigue clothing.

5. Activity in the hot environment - The men were divided into three groups. One group rested for 3 or 4 days before undertaking work in the heat. A second group performed strenuous work for short periods, pedalling a stationary bicycle for ten minutes each hour, five times a day. The third, and largest group, performed more moderate work of longer duration; a work period consisting of a walk of 2-1/2 miles in 47 to 50 minutes with the subject carrying a 20-pound pack. A rest period of 10 to 13 minutes was given between successive work periods. Unless incapacitated the men worked two successive periods in the morning and three in the afternoon, thus walking a total of 12.5 miles a day.

6. Food - The men were given regular army fare obtained from their regular mess. No record was made of the type or amount of food eaten.

7. Water - Salt was added to all drinking water (final concentration, 0.1%). Water intake was measured scrupulously and was administered according to one of three methods:

- a. As much as desired, whenever wanted.
- b. Intake regulated to equal the total fluid lost (sweat, breath).
- c. Restricted to 4 liters, approximately one half of the needed intake, and given in either of two schedules: (1) 270 ml (0.6 pint) every hour from 6:00 A.M. to 6:00 P.M., plus 750 ml (1-2/3 pints) from 6:00 P.M. to 6:00 A.M. (2) 750 ml (1-2/3 pints) at 6:00 A.M., 1250 ml (2-3/4 pints) with noon meal, 1250 ml with evening meal and 750 ml from 6:00 P.M. to 6:00 A.M.

8. Sleep - Eight to nine hours a night. A few men had trouble sleeping early in the experiment, but most slept well throughout.

9. Observations made during the working periods:

- a. General appearance - noted continuously and records kept of vigor, flushing of the face, sweating, headache, and complaints of gastro-intestinal or cardiovascular disturbances.
- b. Rectal temperature - at the beginning and end of each work period.
- c. Heart rate - at the beginning and end of each work period.
- d. Blood pressure - at the beginning and end of each work period.
- e. Weight - the weight within 5 grams was recorded at the beginning and end of the two morning and three afternoon work periods. Subjects were nude and sweat dried off.
- f. The water intake and urine output during each work period, and during each 24-hour period were carefully measured.

10. Urine volume (24 hour output) and specific gravity.

11. Daily urine chloride excretion.

B. FACTORS DETERMINING WATER REQUIREMENTS
IN DESERT CLIMATES

Maintenance of body temperature within narrow limits is essential to life; only small deviations can be tolerated. Temperature regulation is achieved by various physiological mechanisms which serve to adjust the rate of heat loss from the body to equal the rate of heat gain. The heat to be eliminated from the body arises from two sources; (1) internal heat, generated by metabolism, and (2) external heat absorbed from the environment, including the radiant heat from the sun. Four pathways are available for dissipation of this heat: conduction, convection, radiation and evaporation

of sweat. Heat exchange by the first three of these routes, conduction, convection, and radiation, may be positive or negative, that is, they may serve as avenues for the absorption of heat by the body as well as its elimination, depending upon the environmental and skin temperatures. The heat transfer is outward only when the body is at a higher temperature than the surroundings. If the environmental temperature equals the temperature of the body surface, no exchange takes place by these routes. With an environmental temperature greater than that of the body surface, the direction of flow is reversed and heat is delivered to the body from the environment. Under this condition, heat is lost only by evaporation. Schematic illustration of this reversal of heat flow is shown in Fig. 1. Typical rates of heat gain (+) and heat loss (-) are given for an average man (150 lbs., 1.8 M²), in calories per hour, for constant solar radiation* and for various air temperatures above and below body surface temperature. Radiation to or from walls has been calculated on the basis of equality of wall and air temperatures and the convection gain or loss determined for a constant air velocity. The metabolic heat value for resting conditions was employed in the calculations. Any additional metabolic heat generated by work would add to the values shown in Fig. 1.

In spite of the outward transfer of heat by conduction, convection and radiation, at environmental temperatures below 95°, there is a net heat gain to the body since the rate of heat elimination by these routes under the conditions shown in Fig. 1 does not equal the metabolic heat production and solar radiation gain. Thus, for environmental temperatures of 85° and higher, heat elimination by evaporation of sweat is essential for the maintenance of body temperature, even under resting conditions. Sufficient water must be evaporated from the body surface to dissipate the net heat gain shown in Fig. 1.

The cooling effected by the evaporation of water is determined by its latent heat of vaporization which amounts to 580 kilogram calories per liter. If evaporation is complete and no sweat runs off the body, as is the case in arid climates, each liter of sweat secreted and evaporated will dissipate 580 calories of heat. Thus, it is possible to calculate the required sweat output from the heat load imposed on the body. This has been done for the environmental conditions shown in Fig. 1, and the amount of water required is indicated by the scale at the right of the chart.

Sweat is formed from the water of the body and if dehydration is to be avoided the sweat that is evaporated must be replaced by an equal intake of water. Thus, the water requirements for sweating, shown in Fig. 1, also represent the minimum rates of water intake required to prevent dehydration.

* Solar radiation is always positive so long as one is in the open and unprotected.

Sweating is self-regulatory in the sense that when the sweating rate becomes sufficiently high to dissipate the heat load imposed, further sweating does not occur. As a consequence, the rate of sweating and the water requirement vary throughout the day, depending upon the degree of activity and environmental temperature. The effect of ambient temperature is illustrated in Fig. 2. The values for water loss are the averages of results for one person during three 24-hour cycles in the California desert maneuver area in August, 1942.

Precise evaluation of the heat load imposed by metabolism and by the environment is required for prediction of the daily water requirements. There are uncertainties in some of the constants which must be used in such estimates. Of greater importance perhaps, is the fact that any pattern of activity and environmental temperature which is selected in making the calculations, assumes uniformity of behavior and of environment which are never quite met. By moving into the shade, for example, solar radiation is cut off and the water requirement reduced. When in a tent, the radiation and the convection due to wind movement are reduced. Despite such uncontrollable factors, useful predictions of the range of water requirements under various conditions can be made. Estimated daily water requirements arrived at by simplified calculations, are presented in Table 1 for a climate like that of the California desert. These estimates were based upon a daily temperature cycle of the pattern shown in Fig. 3, which depicts the diurnal temperature curve obtained from average hourly temperatures in the California desert during August, 1942. For all maximum temperatures selected, it was assumed that both the pattern and the differences between the maximum and minimum temperatures would remain the same as in the figure.

The total heat gain was calculated in the following manner:

1. Metabolic heat.

The metabolic heat production of a resting man of average size is approximately 2000 calories. If the air temperature is the same (95°F) or higher than skin temperature throughout the day, evaporative dissipation of the entire 2000 calories will be necessary. Even at relatively low air temperatures, some 25% of the metabolic heat is dissipated by insensible perspiration and by evaporation from the lungs. At an air temperature of 85°, as indicated in Fig. 1, some sweating occurs, and the total evaporative dissipation of heat (sweat plus insensible loss) amounts to about 35% of the metabolic heat. The following estimates illustrate the range of variation in water evaporation necessary to dissipate the resting metabolic heat for different maximum daily temperatures. For the day represented in Figure 3 (maximum temperature of 110°) some degree of non-evaporative cooling occurs during 11 out of the 24 hours. During the night the heat loss by radiation and convection amounts to 400 calories and for the same period about 500 calories will be lost by the minimal sweating and insensible perspiration. The remaining 1100 calories (of the 2000) will be dissipated during the day by the evaporative route only.

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Thus, for the 24-hour period, 1600 calories will be lost through evaporation and 400 by radiation and convection. This is equivalent to 1600/580 or 2.8 liters of water required for the shedding of heat from metabolism alone.

With a maximum daily temperature of 95°, the air temperature is below skin temperature most of the time and the total heat dissipated by evaporative cooling requires only about 1.8 liters of water. When the maximum temperature reaches 115°, the air temperature is below 95° for only about 9 hours a day, and approximately 3.0 liters of water are needed to dissipate the total resting metabolic heat. Thus, the variation in water requirements for the removal of resting metabolic heat is not great and for convenience, in Table 1 a value of 2 liters per day has been employed for all temperatures. This tends to overestimate the needs at low temperatures and to underestimate them at high maximum temperatures.

The additional metabolic heat produced by work must be dissipated entirely by evaporation when air temperatures are above skin temperature and even for temperatures down to 85° since, as already shown, the non-evaporative paths of heat loss are inadequate for dissipation of the resting heat produced. Work at a moderate rate will require the expenditure of about 3500 calories in a day, an increase of 1500 calories over and above that contributed by the resting metabolism of 2000 calories. If eliminated entirely by evaporation, 2.6 additional liters of water will be required for dissipation of the heat produced by the added work.

2. Environmental gain.

Environmental heat gain derives from conduction*, convection, radiation from the sun, and radiation from hot surfaces. Convictional gain varies directly with the skin-air temperature difference and the square root of the wind velocity. With a wind velocity of about 4 mph, 17.4 calories will be gained per hour for each °F by which the air temperature exceeds the skin temperature.** In terms of water to be evaporated, this is equivalent to 17.4/580 or 30 ml/hr/°F.

Using the typical day shown in Fig. 3 (max. temperature, 110°F) as an example and assuming a constant rate of air movement, heat will be transferred to the body to an extent determined by the duration of exposure and the skin-air temperature gradient. With an assumed skin temperature of 95° the convection gain will be proportional to the total area between the

* Conduction is usually small and is not considered in these calculations.

** This amount of heat would be gained by a nude individual at a wind velocity of 2 mph and by a person clothed in a suit (with coat and vest) at a wind velocity of 4 mph. With lighter clothing, a wind velocity between 2 and 4 mph will result in the same gain (1.).

upper curve in Figure 3 and the 95° abscissa. This area has the value of 108 degree-hours.* Assuming an air movement of 4 mph and, as explained above, a water equivalent of 30 ml for each degree hour (above skin temperature) the amount of the water to be evaporated, to offset this convection gain during the day, is 30×108 or 3240 ml.

Except in special circumstances such as in tanks with hot walls, radiation gained from hot surfaces is usually small in comparison to other sources of heat gain and may be neglected. The heat gain from solar radiation is approximately equivalent to 320 ml of water per hour (2.) Thus, if 6 hours are spent in the sun, $6 \times 320 = 1920$ ml or 1.9 liters of water will have to be vaporized to dissipate the heat gained.

To recapitulate, the portion of the heat gain that must be lost by evaporation and its equivalent in terms of water are given below for the hypothetical day shown in Fig. 3:

<u>Source of Heat</u>	<u>Heat Gain (Calories)</u>	<u>Equivalent Water (Liters)</u>
Resting metabolism	1600	2.8
Added by moderate work	1500	2.6
Convection	1900	3.2
Sun radiation	<u>1100</u>	<u>1.9</u>
Total	6100	10.5

Water requirements estimated in this way for several degrees of activity and for different maximum daily temperatures, are given in Table 1.

Although the quantities listed in the table are not exact for any single situation, they may be taken as representative of the average needs in desert areas. The calculated requirements correspond well with those measured in the California desert during the summer of 1942. (Project 2-6, dated November 12, 1942.)

In Table 1 no allowance is made for the water needed for urinary excretion. For proper kidney function, this amount should never be less than 600 ml/day. The water contained in the food and that produced by its oxidation will usually be sufficient to yield this amount; consequently, the water required for adequate urine formation need not be considered in the calculations unless the individual is not eating normally. Dry rations, such as K, will require extra water.

Water requirements in relation to desert climate.

Not all desert regions are hot, and for many months of the year the problem of keeping warm is the difficult one. Thus, at Wadi Digla,

* A degree-hour is the product of the time in hours and the difference between air and skin temperatures.

near Cairo in the North African desert, the average daily maximum temperature for December is 68°F; for March 69°F, and during August it rarely exceeds 97° (3.). In the southern and western parts of the Libyan desert somewhat higher temperatures are reached. At Wadi-Halfa, in Anglo-Egyptian Sudan, for example, the average maximum daily temperature is 104°F during August, but, even here, it exceeds 95°F for only 7 months of the year (4.).

The significance of this is that the high water requirements necessitated by extreme temperatures as given in Table 1, must be provided only for certain months of the year, and furthermore, that many desert regions have comparatively mild climates which, at no time, impose abnormally high water requirements. Estimates of water requirements for drinking purposes can be made only on the basis of knowledge of the air temperatures to be encountered in a given theater.

C. EXPERIMENTAL RESULTS

1. WATER REQUIREMENTS.

a. Rate of Sweating. It is possible to compute the heat gain from all sources by measurement of the water loss, provided evaporation is complete, as was the case in these experiments. This was done by weighing the men hourly while resting and before and after a standard walk (2.5 mph with 20-pound pack) of one hour. The resulting data are shown in Fig. 4. The hourly water loss while resting was found to be about 1/2 liter which is equivalent to 290 calories. Since the metabolic rate at rest amounts to 100 cal./hr., the difference of 190 cal/hr. represents the heat gain by convection and radiation which was experienced at the environmental temperature of 120°F. When walking, the average water loss for the group was 1 L/hr. Accordingly, the amount of heat contributed by the extra metabolism of work was 290 cal. (0.5×580) since the gain from radiation and convection remained essentially unchanged in the resting and walking tests. The range of weight losses shown in Figure 4 is a demonstration of the physiological variations which occurred among the subjects.

Rates of sweating during work for both acclimatized and un-acclimatized men may be compared in Fig. 4. Both groups lost, on the average, 1 liter per hour. It may be concluded, therefore, that the process of acclimatization is not accompanied by change in water requirement.

b. Water Restriction. The rate of sweating demanded by a given thermal condition is maintained, in spite of even severe restriction in water intake. Thus, in the present tests, when restricted to 4 liters intake per day, men continue to sweat at a rate equal to that which was maintained when water intake was adequate. The dehydration resulting

from continued sweating with water intake inadequate to make up for the loss leads to deterioration which is already evident with a water deficit of 3-4% of body weight.

Four men who were restricted to a daily water intake of 4 liters per day attempted to carry out the standard hot room program of five 2-1/2 mile walks. Only three succeeded in completing the five periods and these did so with considerable difficulty and discomfort. Some of the effects of the dehydration on performance are shown in Fig. 5 for the three men who completed the five work periods. Restriction of water intake resulted in higher final rectal temperatures, more rapid heart rate, lower blood pressure (in the erect position), and narrower pulse pressure than when adequate water was supplied. The appearance of the men with inadequate water intake revealed even more striking changes. Work was performed with effort and apathy. The eyes became glassy, and the subjects walked in an uncoordinated stumbling manner. They were incapable of sustained purposeful action.

Gradual reduction of the daily water intake over a period of 3 or 4 days to a level of 4 liters per day was tolerated better than was abrupt restriction. Nevertheless, the final condition of the men was the same whether the restriction was gradual or abrupt.

c. Increased Water Intake. Thirst is an inadequate index of fluid requirement for men working in the heat. During these tests, no man voluntarily drank enough water while working to replace that lost in the sweat and all developed water deficits with consequent deterioration of performance. In comparison, when the water intake during work was increased so as to equal the water lost in the sweat, considerable improvement in performance was noted on the first exposure to heat, as demonstrated in the following experiment.

Twelve men were asked to work the full five periods on their first day in the hot room. Of these men, nine received water in amounts sufficient only to quench the thirst (600 ml/hr.) while the other three drank enough to offset that lost by sweating (1200 ml/hr.).

The comparative effects of the 600 ml per hour (6 liters per day) and 1200 ml per hour (9 liters per day) regimens imposed on the two groups of men are compared in Fig. 6, the average data for each group being presented. Observations were obtained at the close of each of the five work periods for the last day in the cool environment, and the first day in the hot environment. Men who did not complete five full periods have been excluded.

The three men who received 1200 ml of water per hour finished all five work periods without great difficulty. Of the other nine men, four became exhausted after three or four work periods and could not continue; those who finished were in a poorer condition and showed greater physiologic disturbances than the men with forced water intake.

2. SALT REQUIREMENTS.

Sweat contains considerable amounts of sodium chloride and other salts. During prolonged sweating, therefore, the salt intake must be increased if depletion of the body salt is to be avoided. At high rates of sweating ordinary diets usually contain insufficient salt to prevent drain on the body's reserve. The sweating rate and water consumption rise more or less in parallel; consequently, water intake constitutes a reliable index of the need for extra salt.

In the absence of sweating, the great bulk of ingested salt is lost in the urine. As sweating increases, however, more and more salt is excreted through the skin, and, consequently if there is no change in the amount of salt ingested, the urinary excretion is greatly reduced. This is shown in Fig. 7. The averaged daily values of salt excreted in the urine for several men in the group studied are shown for the preliminary period of exposure and work in a cool environment and subsequently for the period in hot environment. Upon entering the heat, there was a sharp decline in urinary salt excretion, followed by a gradual increase which, after eleven days, had not returned to the original level.

It has been established that the acclimatized man excretes sweat with a lower salt concentration than does the unacclimatized man. This is consistent with our findings and explains, in part, the gradual increase in urinary salt excretion during continued exposure to the heat (Fig. 7). Some of the decrease in chloride excretion in the early days in the hot environment, however, may have resulted from reduced food (and salt) intake accompanying the loss of appetite which frequently occurs during initial exposure to heat.

Throughout these studies, the men drank a 0.1% solution of salt while in the hot room. The extra salt taken in this manner averaged 5-1/2 gms/per day. If it is assumed that salt intake was constant throughout the period of study, one can estimate the amount of salt lost in the sweat. The daily excretion of chloride during the latter days in the heat was approximately 6 grams less than it was while the men were in the cool environment. The estimated excretion of salt in the sweat amounts, therefore, to 11-1/2 grams per day (6 grams plus 5-1/2 grams ingested with water). It is apparent that serious salt depletion would have occurred in these men during the first few days of exposure to high temperatures if extra salt had not been taken with the drinking water, since the urinary output was only 2-1/2 grams on the second day in the heat, in spite of the increased intake.

The effect of activity on loss of salt in sweat and resulting salt need is indicated by the crossing of the chloride excretion curves for groups 1 and 2 in Figure 7. Group 1, during their working period in the hot room excreted less chloride in the urine, indicating a greater loss in the sweat, than Group 2, who were resting at that time. When their activities were reversed, Group 1 resting and Group 2 working, the urine chloride excretion of the workers was again less than that of the resting group.

1. Gagge, A.P., Winslow, C. - E.A., and Herrington, L.P.,
Amer. Jour. Physiol., 124:30 (1938)
Amer. Jour. Hyg., 26:84 (1937)
2. Adolph, E. F., Amer. Jour. Physiol. 123:486 (1938)
Interim Report No. 1 to Committee on Med. Res.,
Mar. 20, 1943.
3. British Personnel Committee Report, June 23, 1941.
4. Meteorological Office Records, Area F. P. - Upper
Egypt, Sahara, Sudan, etc. (British).

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TABLE 1

CALCULATED DAILY WATER REQUIREMENTS WITH VARYING AMOUNTS
OF WORK AND DIFFERENT AIR TEMPERATURES*

Maximum Daily Temperature F°	Hours Above 95°	Degree- Hours Above 95°	Water Equivalent of Convection Gain Liters	Total Water Equivalent of Metabolic Heat Plus Convection Gain Liters **			
				Rest 2000 Cal.	Light Work 800 extra Cal. 1.4 liters	Moderate Work 1500 extra Cal. 2.6 liters	Strenuous Work 2500 extra Cal. 4.3 liters
95°	0	0	0	2.0	3.4	4.6	6.3
100°	6	16	0.5	2.5	3.9	5.1	6.8
105°	10	53	1.6	3.6	5.0	6.2	7.9
110°	13	108	3.2	5.2	6.6	7.8	9.5
115°	15	178	5.3	7.3	8.7	9.9	11.6

* Solar radiation not included. For 6 hrs. exposure to sun, add 1.9 liters

** 0.95 liters = 1 quart

1 liter = 1.06 quarts

1 milliliter (ml) = .001 liters

FIG. 1

SOURCES OF HEAT GAIN AND MEANS OF HEAT LOSS FOR AN AVERAGE MAN AT VARIOUS TEMPERATURES

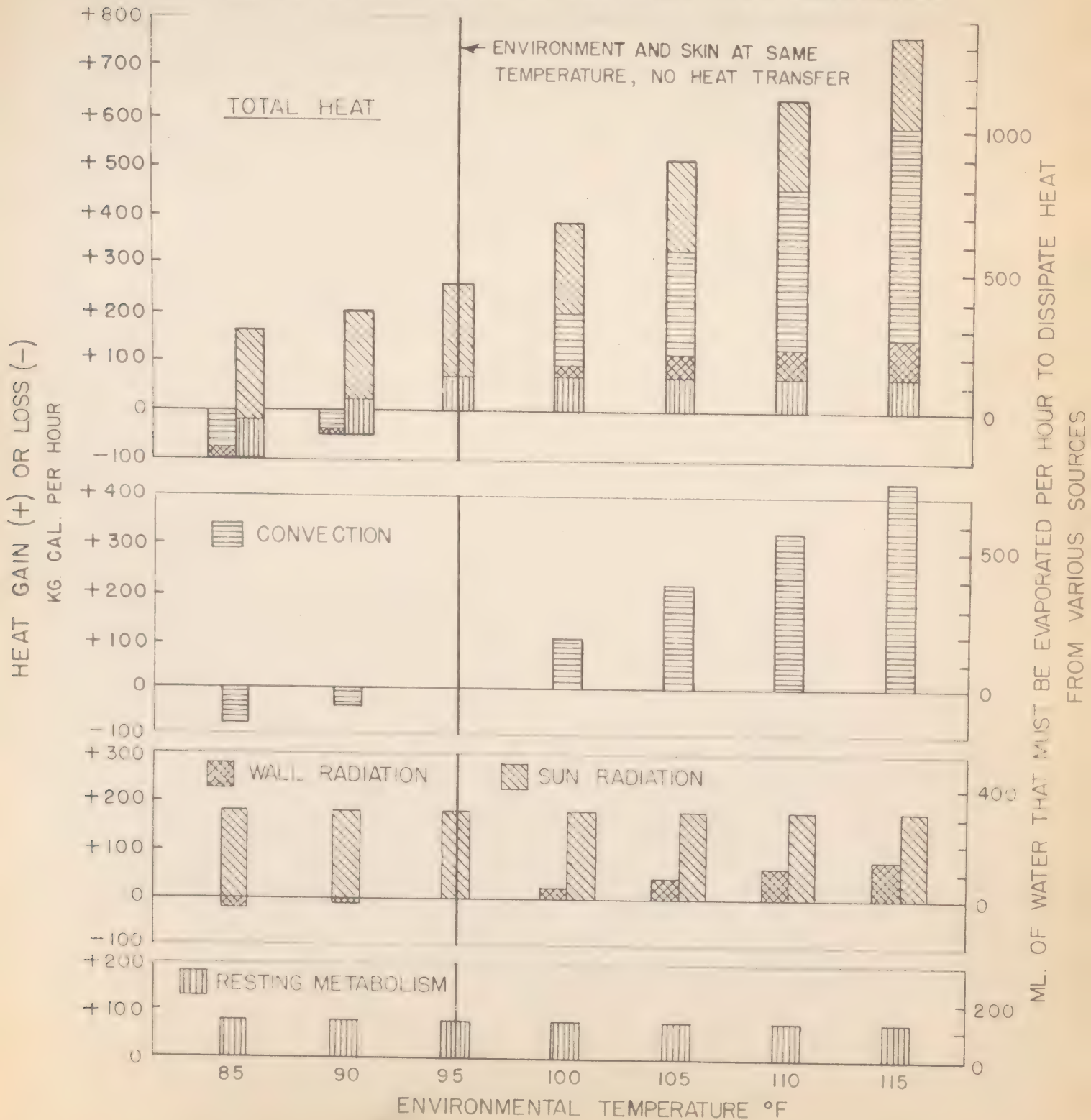


FIG. 1

FIG. 2

RATE OF SWEATING IN RELATION TO AIR TEMPERATURE

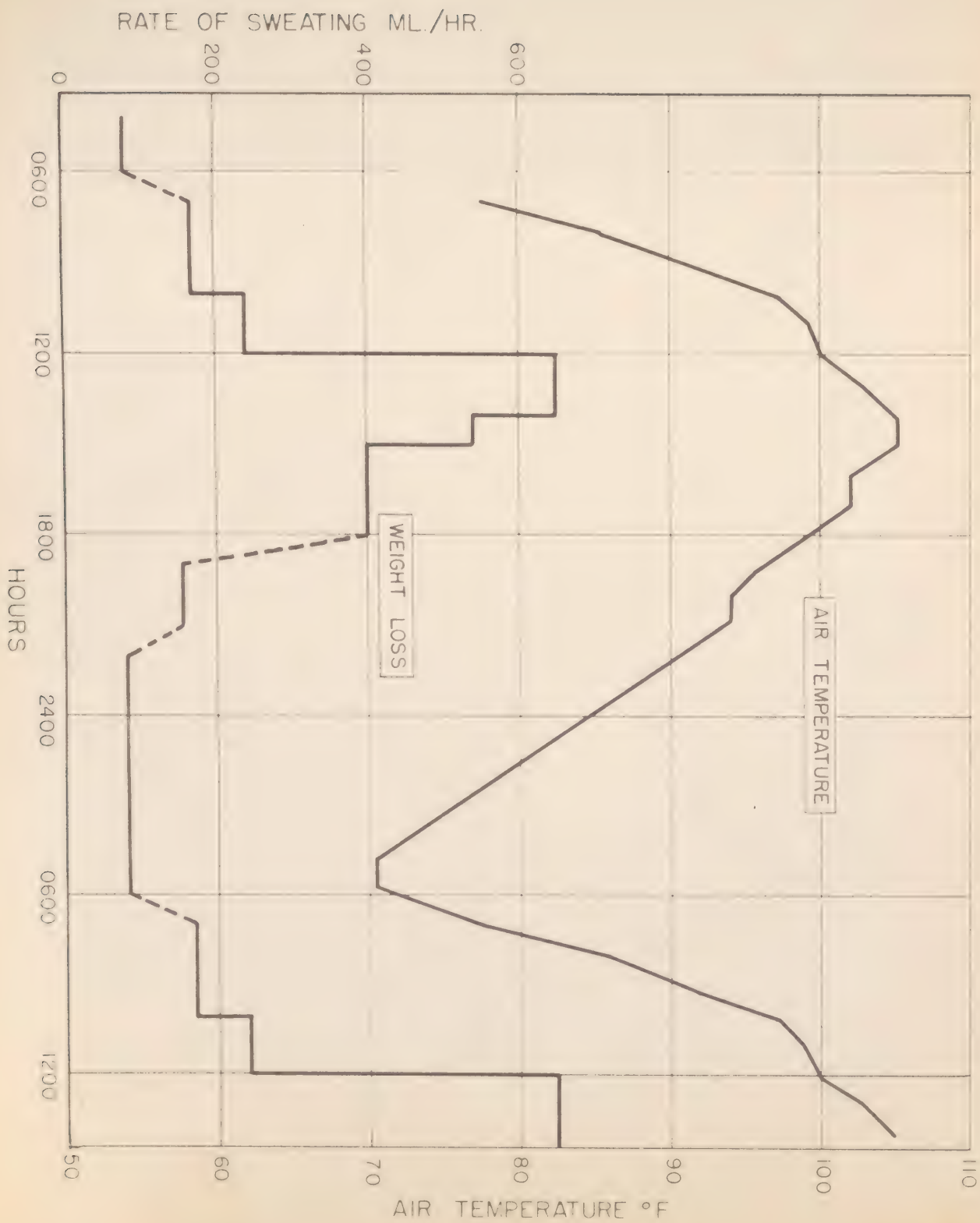


FIG. 2

FIG. 3

TYPICAL DIURNAL TEMPERATURE CURVE FOR A DESERT CLIMATE
SHOWING PERIODS OF POSSIBLE ENVIRONMENTAL HEAT GAIN AND LOSS

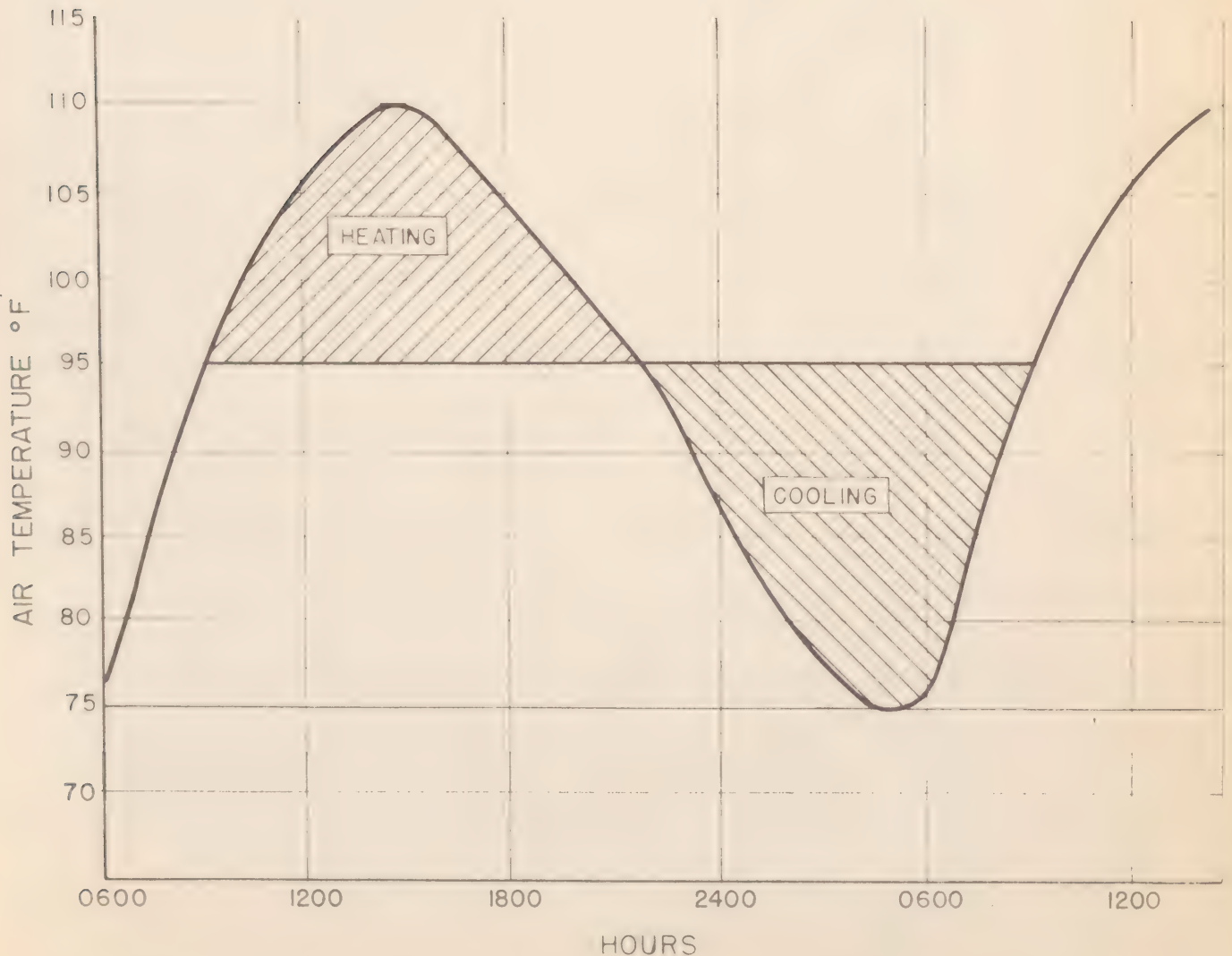


FIG. 3

FIG. 4

RATE OF SWEATING OF RESTING AND WORKING MEN
(AIR TEMP 120°F, RELATIVE HUMIDITY 20%)

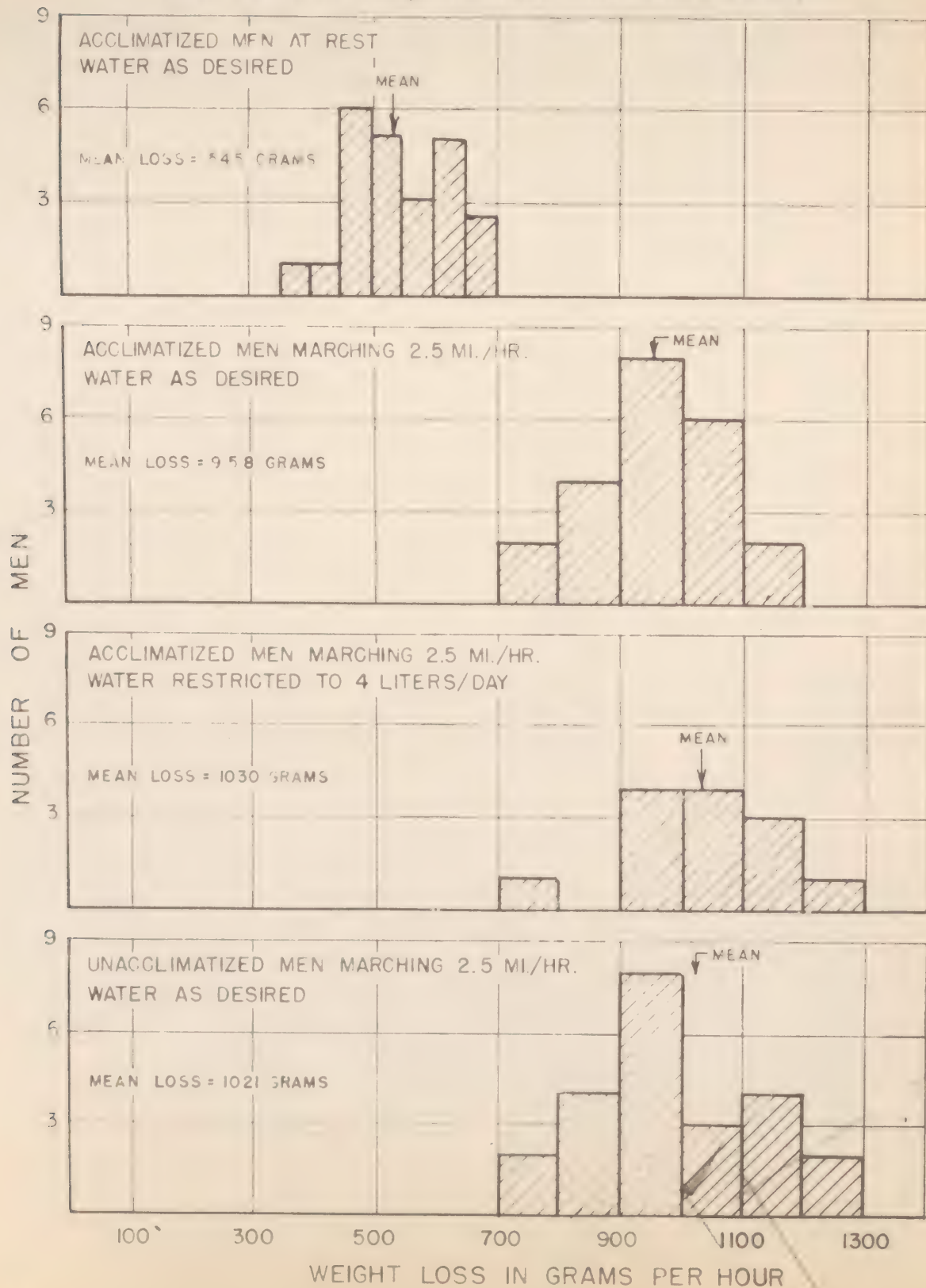


FIG. 4

FIG. 5

EFFECT OF WATER RESTRICTION ON HEART RATE RECTAL TEMPERATURE AND BLOOD PRESSURE

ACCLIMATIZED MEN, RESULTS AT THE END OF THE FIFTH WORK PERIOD

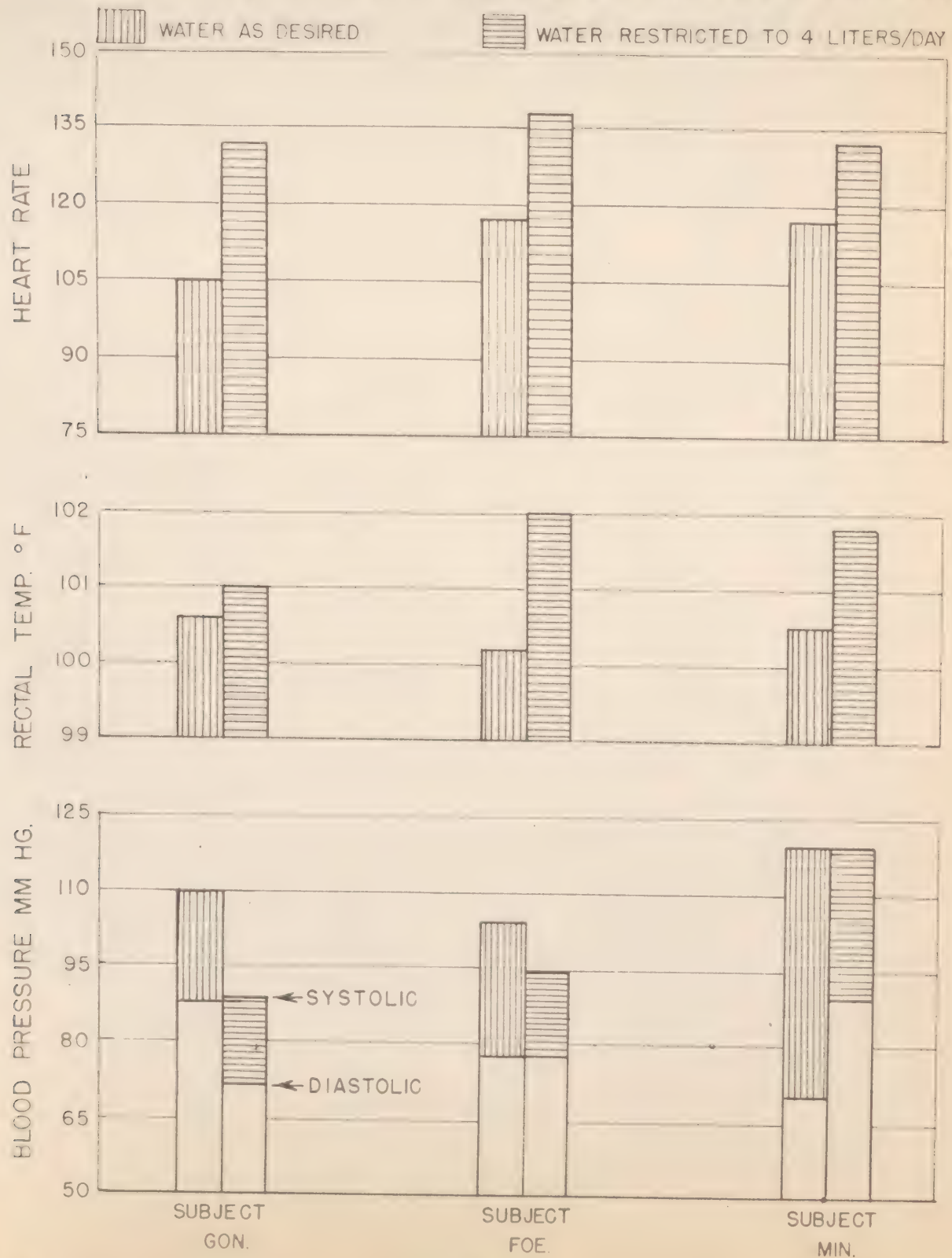


FIG. 5

FIG. 6

PERFORMANCE OF UNACCLIMATIZED MEN WITH MINIMUM WATER INTAKE
AND WITH OPTIMUM WATER INTAKE

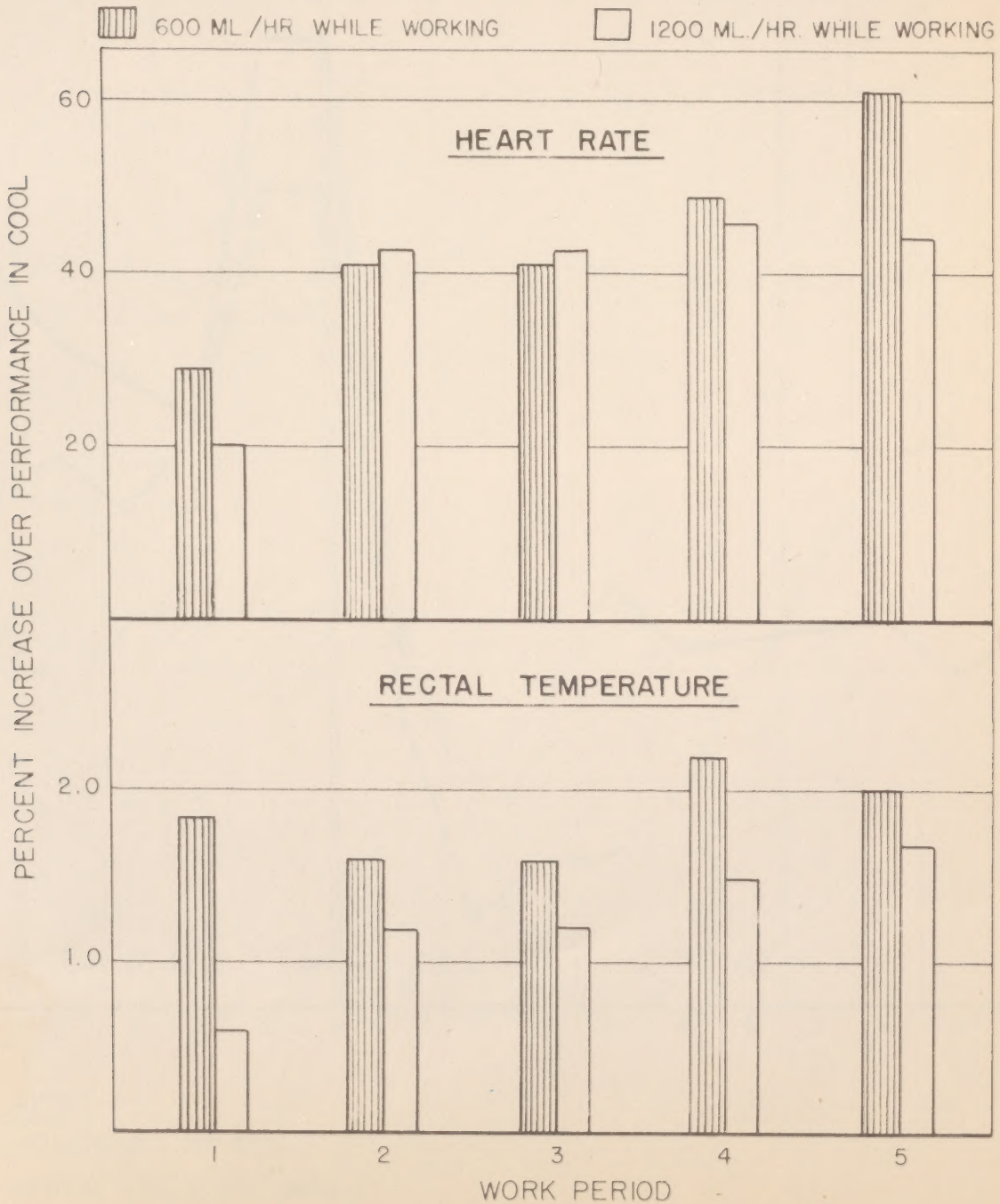
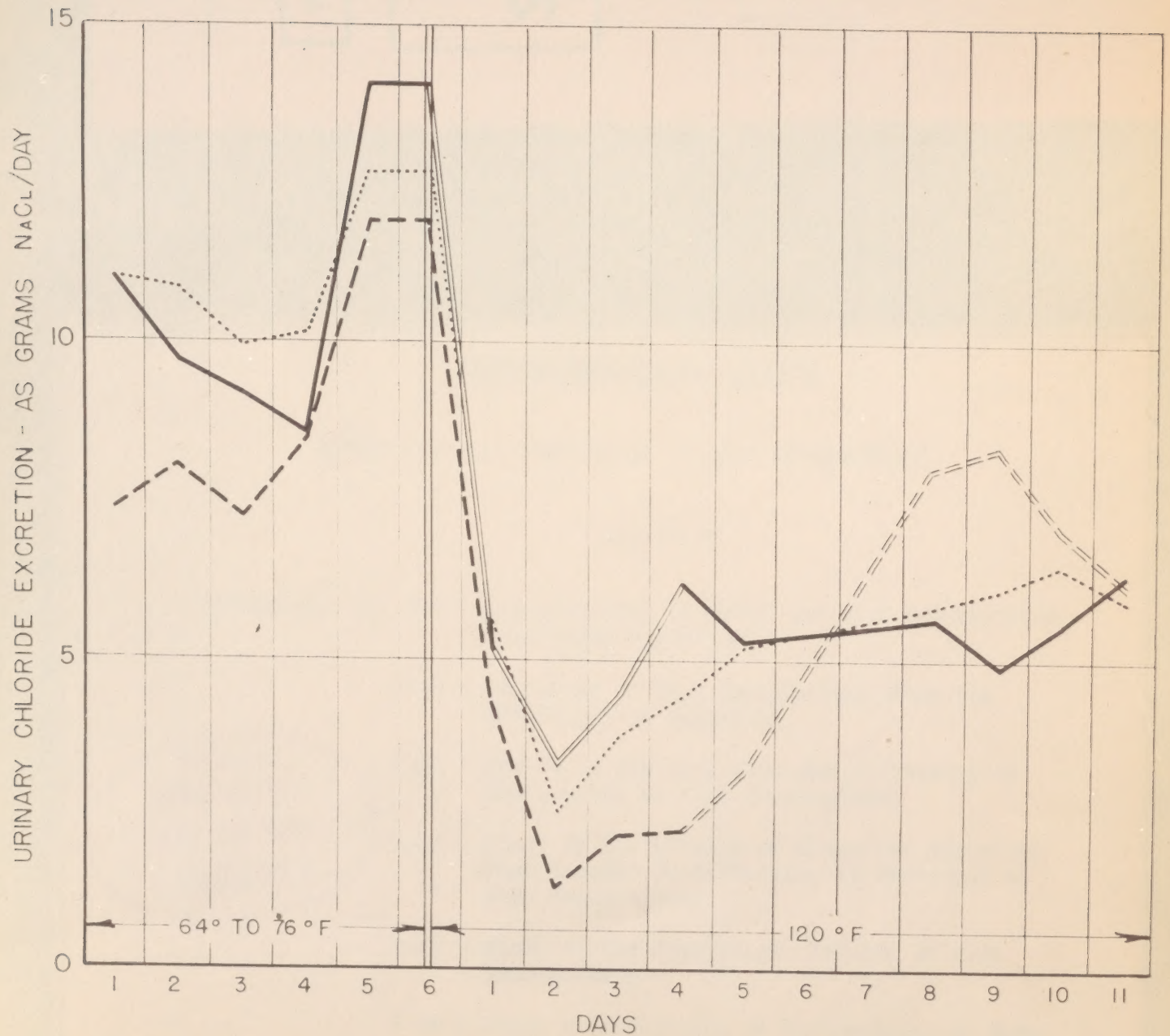


FIG. 6

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FIG. 7

CHLORIDE EXCRETION IN THE URINE



KEY

- AVERAGE ALL (16 MEN)
- HIKE REST
----- AVERAGE GROUP 1 (4 MEN)
- HIKE REST
===== AVERAGE GROUP 2 (4 MEN)

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FIG. 7



CHLORIDE EXCRETION IN THE URINE